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THE MINE COLLABORATION: MULTI-WAVELENGTH OBSERVATIONS OF MICROQUASARS WITH INTEGRAL, PROSPECTS WITH HESS AND ANTARES

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Abstract. We present the international collaboration MINE (Multi- λ Integral NETwork) aimed at conducting multi-wavelength observations of X-ray binaries and microquasars simultaneously with INTEGRAL. The first results on GRS 1915+105 are encouraging and those to come should help us to understand the physics of the accretion and ejection phenomena around a compact object. A collaboration such as MINE could be very useful for observing quasars and microquasars simultaneously with HESS and later with ANTARES.

1 Introduction

Microquasars are X-ray binaries producing relativistic jets and thus they appear as miniature replicas of distant quasars and radio-galaxies (Mirabel & Rodríguez 1999). Their emission spectra, variable with time, range from the radio to the gamma-ray wavelengths. We present here the first multi-wavelength campaign on GRS 1915+105 involving the recently launched INTERNational Gamma-Ray Astrophysics Laboratory (INTEGRAL, 3 keV–10 MeV). This campaign was conducted by the MINE (Multi- λ INTEGRAL NETwork, see <http://elbereth.obspm.fr/~fuchs/mine.html>) international collaboration aimed at performing multi-wavelength observations of galactic X-ray binaries simultaneously with the INTEGRAL satellite.

2 GRS 1915+105

The microquasar GRS 1915+105 has been extensively observed since this source is known to be extremely variable at all wavelengths (see Fuchs *et al.* 2003a for a

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review). It hosts the most massive known stellar mass black hole of our Galaxy with $M = 14 \pm 4 M_{\odot}$ (Greiner *et al.* 2001a). It was the first galactic source to show superluminal ejections (Mirabel & Rodríguez 1994) in the radio domain, which has enabled to give an upper limit of 11.2 ± 0.8 kpc to the distance of the source (Fender *et al.* 1999). In addition to these arcsecond scale ejections, GRS 1915+105 sometimes produces a compact jet which has been resolved at milli-arcsecond scales in radio by Dhawan *et al.* (2000), corresponding to a length of a few tens of AU.

We conducted a multi-wavelength observation campaign of GRS 1915+105 in spring 2003 (see Fig. 1). Here we focus only on April 2–3, when we obtained data covering the widest range of frequencies, with the largest number of involved instruments observing simultaneously with INTEGRAL (Fig. 1). These observations are ToO (Targets of Opportunity) triggered by the MINE collaboration under the INTEGRAL Guaranteed Time Programme and related programmes on the other instruments. We thus present here an overview of the results of a (nearly) simultaneous campaign involving the Very Large Array (VLA), the Very Long Baseline Array (VLBA) and the Ryle Telescope (RT) in radio, the ESO New Technology Telescope (NTT) in IR, the Rossi X-ray Timing Explorer (RXTE) and INTEGRAL in X and γ -rays. More details can be found in Fuchs *et al.* (2003b).

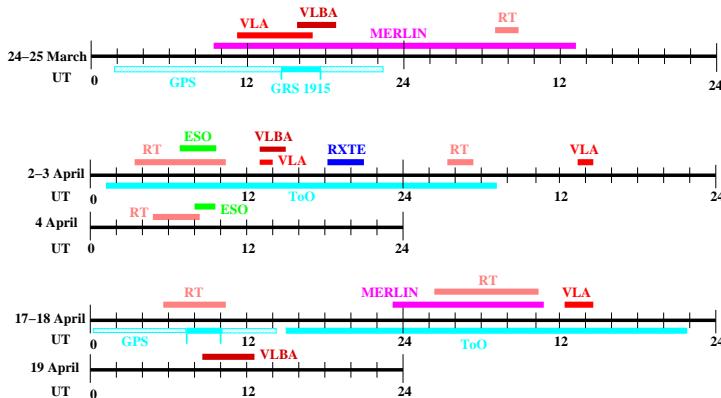


Fig. 1. Viewgraph of the whole observing campaign in spring 2003, indicating the dates, time and involved observatories (GPS = regular Galactic Plane Survey of INTEGRAL). The observations discussed here are those of April 2–3.

Our multi-wavelength observations took place during quasi-quiet periods, with a slowly decaying RXTE/ASM (2–12 keV) flux ~ 50 cts/s and an unusually high radio level (>100 mJy at 15 GHz with the RT). Such bright radio emission accompanied by steady X-ray emission were observed on several past occasions in GRS 1915+105 (see e.g. Fig. 1 of Muno *et al.* 2001). This state is known as the *plateau* state (Fender *et al.* 1999, Klein-Wolt *et al.* 2002 and references therein).

This *plateau* state is also called the radio loud low/hard X-ray state. The high energy emission of GRS 1915+105 on April 2 (Fig. 2) is consistent with this state, with a power law dominated spectrum (77% at 3–20 keV), although always much softer (photon index $\Gamma \sim 3$) than for the other BH binaries in the low/hard state

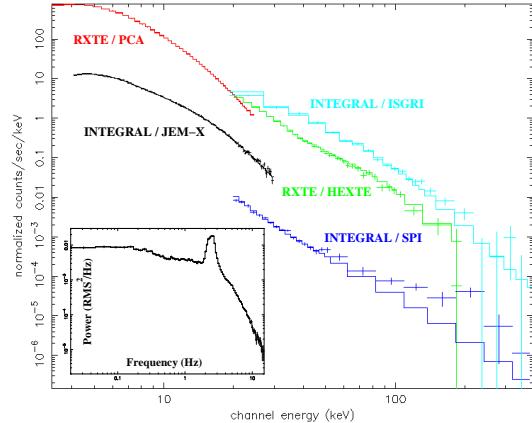


Fig. 2. X/ γ -ray spectra of GRS 1915+105 measured with RXTE (PCA & HEXTE) and INTEGRAL (JEM-X, ISGRI & SPI) on April 2, 2003. Different sensitivities of the instruments lead to different levels of the spectra when plotted in count rates (which enables a better display). The structures at $E>50$ keV in the SPI spectrum are instrumental background lines not adequately corrected. Continuous lines are the best fits showing consistent photon indexes among the different instruments. The PCA power density spectrum (inset) shows a clear QPO at 2.5 Hz.

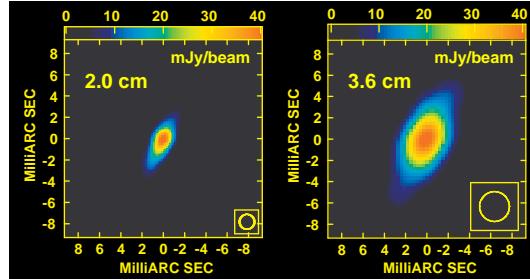


Fig. 3. VLBA images at 2.0 & 3.6 cm on April 2, 2003 showing the compact jet. 1 mas corresponds to 12 AU at 12 kpc distance.

(McClintock & Remillard 2003). The INTEGRAL observations show that this power law spectrum extends up to 400 keV without any cutoff during this *plateau* state, consistent with the observations with CGRO/OSSE (Zdziarski *et al.* 2001). The estimated luminosity is $\sim 7.5 \times 10^{38}$ erg s $^{-1}$ corresponding to $\sim 40\%$ of the Eddington luminosity for a $14M_{\odot}$ black hole. As shown in Fig. 2, a very clear Quasi-Periodic Oscillation (QPO) at 2.5 Hz with a 14% rms level was observed in the RXTE/PCA signal, which is consistent with the *plateau* state of GRS 1915+105.

The VLBA high resolution images (Fig. 3) show the presence of a compact radio jet with a ~ 7 –14 mas length (85–170 AU at 12 kpc). This jet is very similar to the one observed by Dhawan *et al.* (2000) during the 1998 *plateau* state, and is responsible for the high radio levels measured with the RT by its optically thick

synchrotron emission.

The source was fairly bright in near-IR with an excess of 75% to 85% in the K_s -band flux compared to the $K=14.5-15$ mag. of the K-M giant donor star of the X-ray binary (Greiner *et al.* 2001b). According to the spectral energy distribution, this IR excess is compatible with a strong contribution from the synchrotron emission of the jet extending from the radio up to the near-IR. Different components, however, contribute to the IR in addition to the jet, such as the donor-star, the external part of the accretion disc or a free-free emission.

3 Conclusions and Prospects

Here for the first time, we observed simultaneously all the properties of the *plateau* state of GRS 1915+105. We thus confirm the presence of a powerful compact radio jet, responsible for the strong steady radio emission and probably for a significant part of the bright near-IR emission, as well as a QPO (2.5 Hz) in the X-rays and a power law dominated X-ray spectrum with a $\Gamma \sim 3$ photon index up to at least 400 keV. Detailed fits of the RXTE and INTEGRAL spectra of GRS 1915+105 in this *plateau* state, to determine for example whether this power law is due to an inverse Compton scattering of soft disc photons on the base of the compact jet (see e.g. Fender *et al.* 1999) or not, will be studied in forthcoming papers. In our multi-wavelength March-April campaign, the source was observed essentially in the *plateau* state. In order to better understand the unusual behaviour of GRS 1915+105, we need to carry out similar simultaneous broad-band campaigns during the other states, in particular during the sudden changes in the X-ray state that correspond to powerful relativistic ejection events.

The latter, also observed in other microquasars such as XTE J1550–564 or V4641 Sgr, are likely to produce very high energy photon and neutrino emission that could be observed with HESS and ANTARES, respectively.

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